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Comparison of picture impairments caused by digital coding of PAL and SECAM video signals

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COMPARISON OF PICTURE IMPAIRMENTS CAUSED BY DIGITAL CODING OF PAL AND SECAM VIDEO SIGNALS

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Summary

Subjective tests are described which were performed to compare the picture impairment caused by pulse-code modulation (p.c.m.) and differential pulse-code modulation (d.p.c.m.) of PAL and SECAM 625-line video signals. For p.c.m. coding the results indicated that the minimum number of bits per sample required for broadcast quality pictures was the same for both colour systems.

For d.p.c.m. coding, only one particular 5-bit coding law and one form of prediction was examined. This d.p.c.m. coder was originally intended to operate on PAL signals. The resulting impairments were almost imperceptible on most pictures for both PAL and SECAM signals but for the most critical pictures, the impairment was noticeably greater for SECAM than from PAL.

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Section	Title	Page
	Summary	Title Page
1.	Introduction	1
2.	PCM coding	1
	2.1 Test arrangement	1
	2.2 Coding parameters	1
	2.3 Informal subjective tests	1
	2.4 Formal subjective tests	2
3.	DPCM coding	3
4.	Conclusions	4
5.	References	4

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1. Introduction

Previous reports have given results obtained from subjective tests concerning the picture impairment caused by p.c.m. and d.p.c.m. coding of 625-line, PAL (System I) video signals.[1,2] This report describes similar tests on SECAM video signals and the results obtained are compared with those obtained for PAL signals, all other conditions remaining unchanged.

For p.c.m. coding, various numbers of bits per sample and different sampling frequencies were examined. For d.p.c.m. coding only one particular set of coding parameters was examined.

2. PCM coding

2.1 Test arrangement

625-line, 5·5 MHz bandwidth video signals were obtained from either a colour bar generator or a high-quality 35 mm colour slide scanner. After being encoded into PAL or SECAM form, these video signals were passed through an 8-bit p.c.m. codec (combination of coder and decoder)[3], followed by the appropriate colour decoder and the resulting signals were displayed on a 53 cm colour monitor. The brightness of the monitor corresponding to white level was adjusted to be 70 cd/m^2; with zero beam current, the brightness resulting from ambient illumination was 0·1 cd/m^2.

In the p.c.m. coder, the video signal was clamped with the tips of synchronising pulses at the bottom of the conversion range and its amplitude was adjusted so that 100% colour bars just reached the top of the conversion range.

2.2 Coding parameters

Tests were carried out to investigate the impairments introduced by different numbers of bits per sample which could be varied from one to eight by means of switches operating on the digital inputs to the p.c.m. decoder.

As in previous tests on PAL signals[1], the effects of three different sampling frequencies were also examined these being:–

(a) Three times the PAL colour subcarrier frequency (13·301 MHz)
(b) 851 times line frequency (13·297 MHz)
(c) An unlocked frequency (13·277 MHz)

The frequency (c) was selected to be close to (a) and (b) and was such as to give a high visibility beat pattern on coloured areas when coding with low numbers of bits per sample. These frequencies will be denoted by $3\ f_{sc}$, $851\ f_L$ and 'unlocked' respectively.

The $3\ f_{sc}$ sampling frequency signal for PAL was obtained by selecting the third harmonic of an oscillator locked to the colour burst; for SECAM signals, it was provided by a crystal-controlled frequency synthesiser set to the same frequency as used for PAL. The frequency synthesiser was also used to provide the $851\ f_L$ and unlocked sampling frequencies for both PAL and SECAM.

2.3 Informal subjective tests

From informal subjective tests carried out by three or four experienced viewers, the following conclusions were reached.

With dither* in use, the degree of impairment obtained with a given number of bits per sample and a given sampling frequency was very similar for both PAL and SECAM signals and was independent of picture content. For reference purposes, the impairment grade obtained from PAL signals with dither in use at various bits per sample is shown in Fig. 1. This curve applies to all three sampling frequencies discussed in Section 2.2. The degree of impairment corresponding to different grades is given in Table 1.

Table 1
Impairment Grading Scale

Grade	Impairment
1	Imperceptible
2	Just perceptible
3	Definitely perceptible but not disturbing
4	Somewhat objectionable
5	Definitely objectionable
6	Unusable

With no dither in use, it was again found that with most picture sources there was little difference in the impairment grade obtained with PAL and SECAM signals particularly if the noise generated by the original picture source was sufficient to act as an efficient dither signal. However, with some critical pictures containing large

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*The dither signal consisted of a half-sampling frequency component with an amplitude equal to one half a quantum step and a pseudo-random component with 8 levels having equal probability of occurrence, the spacing between levels being $\frac{1}{16}$ of a quantum step.

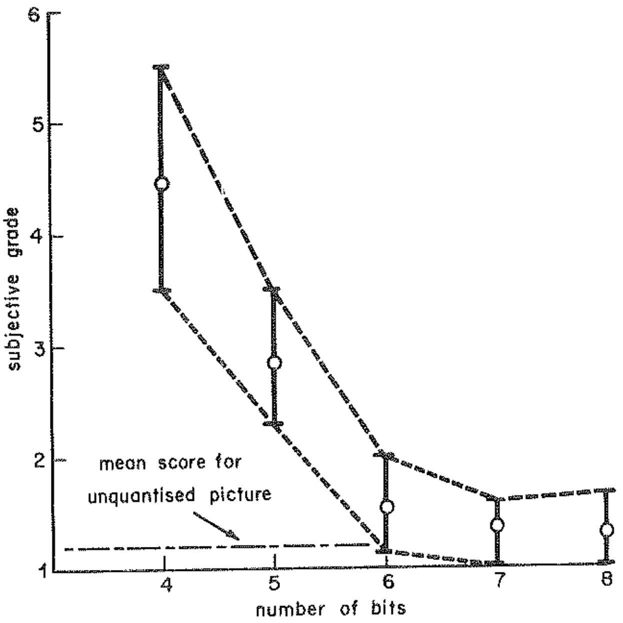

Fig. 1 - Subjective impairment of PAL signals at different numbers of bits per sample with dither in use

I *Variation in mean grade for different picture sources*

O *Mean grade for all picture sources*

coloured areas with little luminance detail, significant differences in the appearance of the quantising distortion could be observed at relatively low numbers of bits per sample. As an indication of the differences in impairment for critical pictures, estimates were made of the impairment of EBU colour bars at various numbers of bits per sample for both PAL and SECAM signals, bearing in mind the results of previous tests on PAL signals.[1] The results are shown in Fig. 2. Tests performed to check these results are described in Section 2.4 which also includes a discussion of the results.

The conclusion that there is little difference between the impairment grades obtained with PAL and SECAM signals at six or more bits per sample on normal pictures (not test signals) both with and without dither is substantiated by the results of tests carried out by the RAI laboratories in Turin.[4]

2.4 Formal subjective tests

Two test pictures were used in the formal tests, these being EBU colour bars and a picture from a 35 mm slide scanner; a monochrome version of the slide is shown in Fig. 3. This slide was chosen as it had previously been used in the tests on PAL signals.[1]

All three sampling frequencies mentioned in Section 2.2 were examined but in order to limit the number of tests, the number of bits per sample was kept constant at 5 bits. This number of bits was chosen as a compromise between good picture quality and a clear indication of the differences in the impairments produced by the various test conditions; also, at 5 bits per sample, the effects of instrumental errors in the p.c.m. codec were small compared with the fundamental errors due to quantisation.

Six experienced observers were seated at between 4 and 6 times picture height, and asked to grade the picture quality according to the impairment scale given in Table 1. The unquantised picture was shown before each test picture using the same colour coding system as in the test condition. The various test conditions were shown in random order.

The results of these formal tests are given in Table 2. The grades shown are the mean grades given by the six observers and σ_m represents the standard error of these mean grades.

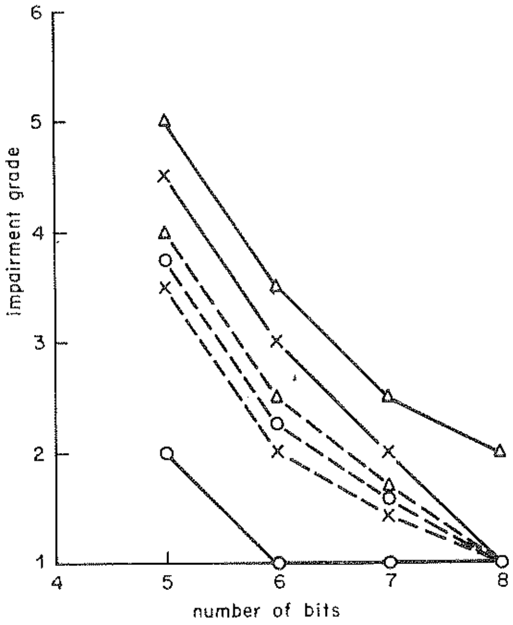

Fig. 2 - Impairment of PAL and SECAM EBU colour bar; p.c.m.; no dither

——— *PAL signals*

- - - - *SECAM signals*

O *Sampling frequency = 3 f_{sc}*

X *Sampling frequency = 851 f_L*

Δ *Sampling frequency unlocked*

It can be seen that the results for the formal tests on colour bars were in good agreement with those obtained from informal tests, apart from the grades being slightly higher overall for the formal tests. Both types of subjective test agree that bear-patterning effects due to quantisation of the colour subcarrier are less noticeable for SECAM signals than for PAL signals at the unlocked and 851 f_L sampling frequencies but are rather more noticeable for SECAM at the 3 f_{sc} frequency. However, it should be mentioned that, for 3 f_{sc} sampling of PAL signals, no contouring or beat patterning effects occur in areas of precisely constant luminance, due and saturation, and hence colour bars give abnormally low impairment grades compared with normal pictures in which these features do not remain constant over large areas.

The results in Table 2 for the slide agree with the informal tests for slides (not detailed here) that there is little difference between the impairments of PAL and

Table 2

Results of formal subjective tests on p.c.m. using 5 bits per sample and no dither

Picture	Colour System	Sampling Frequency					
		3 f_{sc}		851 f_L		Unlocked	
		Grade	σ_m	Grade	σ_m	Grade	σ_m
Colour Bars	PAL	2·2	0·4	5·1	0·2	5·9	0·1
(EBU)		(2)*		(4·5)		(5)	
	SECAM	4·4	0·2	3·9	0·4	4·7	0·3
		(3·7)		(3·5)		(4)	
Slide	PAL	3·4	0·5	3·5	0·4	4·5	0·2
	SECAM	3·2	0·4	2·8	0·5	3·3	0·4

*The grades in brackets are the results of the informal tests taken from Fig. 2

SECAM signals derived from pictures other than test signals at the 3 f_{sc} and 851 f_L sampling frequencies. However, the impairment of the PAL picture was significantly greater than that of the SECAM picture at the unlocked sampling frequency; this result is typical for pictures having large plain coloured areas such as the background of this slide. The informal tests indicated that for the majority of pictures there was little difference between the impairment for PAL and SECAM even at the unlocked sampling frequency.

The results for both colour bars and the slide indicate that SECAM signals are slightly less impaired at the line-locked sampling frequency than at the other frequencies whereas PAL signals are least impaired at the subcarrier locked frequency.

Fig. 3 - Monochrome version of slide used in subjective tests

An advantage of SECAM signals which was observed on a colour bar picture was that slight quantising errors resulting from instrumental defects in the PCM coder were less visible with SECAM than with PAL. For example, slight patterning caused by instrumental defects could be observed on a display of a PAL colour bar signal with 8 bits per sample and the unlocked sampling frequency but no impairment was perceptible on SECAM colour bars with 8 bits per sample at any sampling frequency.

3. DPCM coding

This section describes tests performed to compare the picture quality obtained with PAL and SECAM video signals after these signals and passed through a differential pulse-code modulation (d.p.c.m.) system designed to provide high-quality pictures with PAL video signals.[2]

The basic principles of the d.p.c.m. encoder were as follows. The video signal was first converted into an 8-bit p.c.m. signal at a sampling frequency of three times the PAL subcarrier frequency. This p.c.m. signal was processed by digital means to obtain a difference signal which basically indicated the change in level between every third sample of the p.c.m. signal. The number of bits required for the d.p.c.m. signal is reduced to 5 bits by passing the difference signal through a non-linear quantiser with only 32 output levels. The characteristic of this non-linear law was such that small differences were encoded with the same accuracy as in 8-bit p.c.m. but large differences were encoded less accurately; also the maximum difference which could be transmitted was ± 104 q where q represents the difference in level between adjacent quantum levels in 8-bit p.c.m. For comparison, the difference between black and white levels is about 140 q when the magnitude of the composite colour signal is adjusted to just fill the conversion range of the 8-bit p.c.m. coder.

For PAL signals, the advantage of coding the difference between every third sample rather than successive samples is that the presence of colour subcarrier has virtually no effect on the amplitude of the difference signal when the sampling frequency is 3 f_{sc}; as a result, the colour signal including the subcarrier is encoded with 8-bit accuracy in low-detail areas of a picture. With SECAM signals, however, the use of frequency modulation and different mean frequencies on alternate lines for the colour subcarrier makes it impossible to sample continuously at an integral multiple of subcarrier frequency; as a result, the magnitude of the difference signal, and hence the coding accuracy, depends on the hue and saturation of the colour to be transmitted. For optimum results, the sampling frequency should be set to three times the mean frequency of the SECAM colour subcarrier which is about 13·0 MHz. It was found, however, that the overall picture impairment obtained at 13·0 MHz was very similar to that obtained at 13·3 MHz (i.e. 3 f_{sc}). For convenience, therefore, when comparing the effects of d.p.c.m. coding for PAL and SECAM signals, it was decided that a sampling frequency of exactly three times the PAL subcarrier frequency (3 f_{sc}) would be used for both types of signal.

The general conditions of the subjective tests on d.p.c.m. coding were identical to those described for p.c.m. coding. The results of the tests are given in Table 3.

Table 3

Results of subjective tests on 5-bit d.p.c.m. system using tapered quantising law

Picture	Colour System	Impairment Grade
EBU Colour Bars	PAL	1·4
	SECAM	2·7
Slide	PAL	1·0
(See Fig. 3)	SECAM	1·2

These results confirmed informal observations of a wider variety of pictures that the 5-bit d.p.c.m. coding system used in the tests caused neglibilbe picture impairment with both PAL and SECAM signals for most types of picture material but for very critical pictures, such as colour bars, the impairment for SECAM signals was greater than that permissible for a broadcast-quality transmission system.

4. Conclusions

The results of subjective tests comparing p.c.m. coding of PAL and SECAM video signals indicate that, if dither is used, there is no significant difference in the picture impairments for the two colour systems. If no dither is in use, then the picture impairment is, in general, marginally less noticeable for SECAM than for PAL signals but this is not sufficient to warrant the use of less bits per sample for SECAM than for PAL.

From these results it is concluded that for broadcast-quality pictures the number of bits per sample required for p.c.m. coding of SECAM signals should be the same as those specified for PAL in a previous report, i.e. 7 bits per sample with dither, or 8 bits per sample without dither, if the video signal is subjected to only one p.c.m. coding and decoding operation; using 8 bits per sample with dither, the video signal could be subjected to four p.c.m. coding and decoding operations.

The tests also indicated that the picture impairment of SECAM signals is minimised if the sampling frequency is locked to an integral multiple of line frequency. However, the variation in impairment obtained with the three different sampling frequencies used in the tests was insignificant when using the number of bits per sample required for broadcast quality pictures.

For a particular 5-bits-per-sample d.p.c.m. coding system which was designed for use with PAL signals and employed a tapered quantising law, it was found that the impairment of SECAM signals was negligible (no greater than grade 1·5) for most types of picture but was definitely perceptible on critical pictures. For PAL signals, the impairment was judged to be no greater than grade 1·5 on all types of picture.

5. References

1. DEVEREUX, V.G. 1971. Pulse code modulation of video signals: subjective study of coding parameters. BBC Research Department Report No. 1971/40.

2. DEVEREUX, V.G. 1973. Digital video: differential coding of PAL signals based on differences between samples one subcarrier period apart. BBC Research Department Report No. 1973/7.

3. DEVEREUX, V.G. 1970. Pulse-code modulation of video signals: 8 bit coder and decoder. BBC Research Department Report No. 1970/25.

4. BARBIERI, G.F. et al. 1971. Determination of the fundamental parameters of a linear p.c.m. video systems by means of subjective tests. RAI Technical Report No. 71/20/E.

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